MULTIMEDIA UNIVERSITY ™

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 1, 2017/2018

ETN3046 – ANALOG AND DIGITAL COMMUNICATIONS

(CE, EE, LE, ME, NE & OPE)

21 OCTOBER 2017
9:00 AM – 11:00 AM
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This Question paper consists of 9 pages (including this cover page) with 4 Questions only and an appendix.

2. Attempt **ALL** questions. All questions carry equal marks and the distribution of the marks for each question is given.

3. Please print all your answers in the Answer Booklet provided.

Question 1

(a) Modulation is a process of changing the carrier in proportion with the message signal. Describe the differences between Frequency Modulation (FM) and Frequency Shift Keying (FSK).

[2 marks]

(b) Before modulation, a signal $x(t)$ has the spectral characteristic being expressed as $X(f)=\frac{1}{1+j2\pi f}$. The function $y(t)$ is the result of modifying $x(t)$ before the modulation process. Let $Y(f)$ denote the Fourier transform of $y(t)$. Express $Y(f)$ in terms of $X(f)$ based on the following relations:

(i) $y(t) = x(t - 1)$ [3 marks]

(ii) $y(t) = e^{-jt}\, x(t)$ [3 marks]

(c)

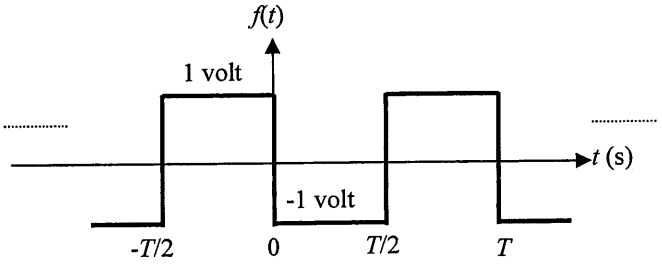

Fig. Q1.1 Periodic amplitude waveform

Fig. Q1.1 shows a periodic amplitude waveform that can be expressed in the form of trigonometric Fourier series as follows:

$$f(t) = A_0 + \sum_{n=1}^{\infty} A_n \cos\left(\frac{2\pi nt}{T}\right) + \sum_{n=1}^{\infty} B_n \sin\left(\frac{2\pi nt}{T}\right)$$

where

$$A_0 = \frac{1}{T}\int_T f(t)\ dt$$

$$A_n = \frac{2}{T}\int_T f(t)\cos\left(\frac{2\pi nt}{T}\right) dt$$

$$B_n = \frac{2}{T}\int_T f(t)\sin\left(\frac{2\pi nt}{T}\right) dt$$

T is the period of the waveform. Given $T = 2$ seconds, find the value of A_0. Determine the expressions for A_n, B_n, and their respective values for $n = 1, 2, 3, 4$.

[8 marks]

Continued ...

Question 1 (Continued)

(d) A sinusoidal wave $m(t) = A_m\cos(2\pi f_m t)$ amplitude-modulates a sinusoidal carrier of amplitude A_c and frequency f_c, resulting in an amplitude-modulated (AM) wave that is expressed as follows:

$$s(t) = A_c\cos(2\pi f_c t) + \frac{A_c\mu}{2}\cos[2\pi(f_c + f_m)t] + \frac{A_c\mu}{2}\cos[2\pi(f_c - f_m)t]$$

It is given that

Amplitude of the message signal, A_m = 8 V
Frequency of the message signal, f_m = 1 kHz
Amplitude of the carrier, A_c = 20 V
Frequency of the carrier, f_c = 200 kHz
Modulation factor, μ = 0.8

The AM wave is supplied to a load of **10 Ω**.

(i) Determine the power dissipated across the load at the **carrier** frequency. [2 marks]

(ii) Determine the power dissipated across the load at the **sidebands**. [2 marks]

(iii) Determine the **total** power dissipated across the load due to this AM wave. [2 marks]

(iv) Sketch the one-sided power spectrum of this AM wave. [3 marks]

Question 2

(a) Fig. Q2.1 shows a single sideband (SSB) modulator. Assume that the message signal is given by $m(t) = A_m\cos(2\pi f_m t)$.

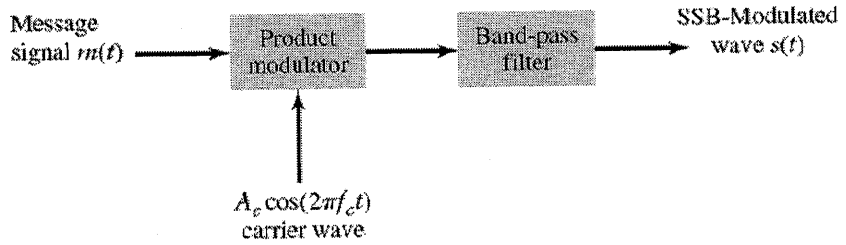

Fig. Q2.1 Single sideband modulator

Determine the amplitude spectrum of the modulated signal $s(t)$ when the following is selected by the band-pass filter. Sketch the amplitude spectrum and label the sketches clearly.

(i) Upper single sideband (USSB) [4 marks]

(ii) Lower sideband (LSSB) [4 marks]

Continued ...

Question 2 (Continued)

(b) Consider a frequency-modulated (FM) signal that is expressed as follows:

$$x(t) = A\cos\left[2\pi f_c t + B\int_0^t \cos(2\pi f_m \tau)d\tau\right]$$

where A and B are constants.
Write down the respective expressions for the following quantities:

(i) Message signal, $m(t)$ [1 mark]
(ii) Instantaneous phase deviation, $\Delta\theta_i(t)$ [integration must be solved] [2 marks]
(iii) Instantaneous phase, $\theta_i(t)$ [1 mark]
(iv) Angular frequency deviation, $d\,[\Delta\theta_i(t)]\,/dt$ [2 marks]

(c) A carrier signal is frequency modulated (FM) by a sinusoidal signal of frequency f_m = 25 kHz. Modulation index $\beta = 1$. The FM wave is supplied to a load of $R\ \Omega$.

(i) Estimate the bandwidth of the FM signal based on the Carson's rule. [2 marks]

(ii) Estimate the bandwidth of the FM signal by referring to the table of Bessel function of the first kind. [2 marks]

(iii) Determine the percentage of power contained at the carrier frequency. [3 marks]

(iv) Determine the percentage of power contained at the first sidebands. [2 marks]

(v) Determine the percentage of power contained at the second sidebands. [2 marks]

Table Q2.1: Table of the Bessel Function of the First Kind

	$J_n(\beta)$			
n	$\beta = 1.0$	$\beta = 2.0$	$\beta = 3.0$	$\beta = 5.0$
0	0.765	0.224	-0.260	-0.178
1	0.440	0.577	0.339	-0.328
2	0.115	0.353	0.486	0.047
3	0.020	0.129	0.309	0.365
4		0.034	0.132	0.391
5			0.043	0.261
6			0.011	0.131
7				0.053
8				0.018

Continued ...

Question 3

(a) (i) Sketch the block diagram of a digital communication system and label its components accordingly.

[4 marks]

(ii) Assuming instantaneous (ideal) sampling, briefly describe how does the spectrum of the sampled signal $m_s(t)$ differ from the spectrum of the original signal $m(t)$. Using some appropriate figures, illustrate the spectrum of an exemplary bandlimited signal, if instantaneous sampling is performed at the Nyquist rate.

[5 marks]

(b) (i) Briefly describe why non-uniform quantization is preferred over uniform quantization in the pulse code modulation (PCM) encoder of telephonic communications. Discuss how it is accomplished indirectly in practice using a compression characteristic.

[4 marks]

(ii) When a μ-law compressor is used in PCM, the output signal-to-quantizing noise ratio for $\mu >> 1$ is approximated by

$$\left(\frac{S}{N}\right) \approx \frac{3L^2}{\left[\ln(1+\mu)\right]^2}$$

where L is the number of quantization levels. For the case of $\mu = 255$, derive the output signal-to-quantizing noise ratio in terms of the number of binary bits and express your answer in the form of the 6 dB rule.

[3 marks]

(c) (i) Briefly describe with the aid of diagrams the two types of quantization noise in delta modulation (DM).

[4 marks]

(ii) What is the rationale behind the development of adaptive DM (ADM)? Briefly describe its underlying working principle.

[5 marks]

Continued ...

Question 4

(a) (i) For a digital data sequence of {1 0 1 0 1 0}, sketch the waveforms of amplitude-shift keying (ASK), frequency-shift keying (FSK) and phase-shift keying (PSK) modulated signals. Make your own assumptions on the bit-to-waveform assignment for these three digital modulation schemes. [4 marks]

(ii) Briefly explain quadrature amplitude modulation (QAM) and state its advantage over modulation schemes such as ASK, FSK PSK. [3 marks]

(b) A discrete memoryless source generates five messages $\{s_1, s_2, s_3, s_4, s_5\}$ with respective probabilities of occurrence $\{0.05, 0.2, p_3, 0.1, 0.25\}$.

(i) Determine p_3, i.e., the probability of occurrence for symbol s_3. [1 mark]

(ii) Determine the entropy of the source. [3 marks]

(iii) Obtain the Huffman code for these messages by moving a combined symbol as high as possible. [7 marks]

(c) Consider a Hamming (7,4) code with the following parity-check matrix **H**.

$$\mathbf{H} = \begin{bmatrix} 1 & 0 & 1 & 1 & 1 & 0 & 0 \\ 1 & 1 & 1 & 0 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 & 0 & 0 & 1 \end{bmatrix}$$

(i) Calculate the efficiency and redundancy of the Hamming code. [2 marks]

(ii) Given that codeword 1001111 is received, calculated the syndrome and investigate if an error has occurred. If it has, determine the correct codeword. [5 marks]

End of Questions

APPENDIX

Table of Fourier Transform Pairs

$x(t)$	$X(f)$
$\delta(t)$	1
$\delta(t-t_o)$	$e^{-j2\pi ft_o}$
1	$\delta(f)$
$e^{j2\pi f_o t}$	$\delta(f-f_o)$
$u(t)$	$\frac{1}{2}\delta(f)+\frac{1}{j2\pi f}$
$e^{-at}u(t)$	$\frac{1}{a+j2\pi f}$, for $a>0$
$e^{at}u(-t)$	$\frac{1}{a-j2\pi f}$, for $a>0$
$e^{-a\lvert t\rvert}$	$\frac{2a}{a^2+(2\pi f)^2}$, for $a>0$
$rect\left(\frac{t}{T}\right)$	$T\text{sinc}(fT)$
$\text{sinc}(2Wt)$	$\frac{1}{2W}rect\left(\frac{f}{2W}\right)$
$\Delta\left(\frac{t}{T}\right)$	$\frac{T}{2}\text{sinc}^2\left(\frac{fT}{2}\right)$
$W\text{sinc}^2(Wt)$	$\Delta\left(\frac{f}{2W}\right)$
$e^{-\pi t^2}$	$e^{-\pi f^2}$
$\cos(2\pi f_o t)$	$\frac{1}{2}\delta(f-f_o)+\frac{1}{2}\delta(f+f_o)$
$\sin(2\pi f_o t)$	$\frac{1}{2j}[\delta(f-f_o)-\delta(f+f_o)]$
$\text{sgn}(t)=\begin{cases}1 & t>0\\-1 & t<0\end{cases}$	$\frac{1}{j\pi f}$
$\frac{1}{\pi t}$	$-j\,\text{sgn}(f)$

Table of Fourier Transform Properties

Let $x(t) \Leftrightarrow X(f)$, $x_1(t) \Leftrightarrow X_1(f)$ and $x_2(t) \Leftrightarrow X_2(f)$; and a, b, t_o and f_o scalar quantities.	
Linearity	$ax_1(t)+bx_2(t) \Leftrightarrow aX_1(f)+bX_2(f)$
Duality	$X(t) \Leftrightarrow x(-f)$
Scaling ($a \neq 0$)	$x(at) \Leftrightarrow \frac{1}{\lvert a \rvert} X\left(\frac{f}{a}\right)$
Time Shifting	$x(t-t_0) \Leftrightarrow X(f)e^{-j2\pi ft_0}$
Frequency Shifting	$x(t)e^{j2\pi f_0 t} \Leftrightarrow X(f-f_0)$
Modulation	$x(t)\cos(2\pi f_0 t) \Leftrightarrow \frac{1}{2}X(f-f_0)+\frac{1}{2}X(f+f_0)$
Time Convolution	$x_1(t) * x_2(t) \Leftrightarrow X_1(f)X_2(f)$
Frequency Convolution	$x_1(t)x_2(t) \Leftrightarrow X_1(f) * X_2(f)$
Time Differentiation	$\frac{d^n}{dt^n}x(t) \Leftrightarrow (j2\pi f)^n X(f)$
Frequency Differentiation	$(-jt)^n x(t) \Leftrightarrow \frac{d^n}{df^n}X(f)$
Time Integration	$\int_{-\infty}^{t} x(\tau)d\tau \Leftrightarrow \frac{X(f)}{j2\pi f}+\frac{1}{2}X(0)\delta(f)$
Frequency Integration	$x(t)u(t) \Leftrightarrow \int_{-\infty}^{f} X(\tilde{f})d\tilde{f}$

Useful Trigonometric Identities

$$\sin A \sin B = \frac{1}{2}[\cos(A-B) - \cos(A+B)]$$

$$\cos A \cos B = \frac{1}{2}[\cos(A+B) + \cos(A-B)]$$

$$\sin(A+B) = \sin A \cos B + \cos A \sin B$$

$$\cos(A+B) = \cos A \cos B - \sin A \sin B$$

$$\sin\theta = \frac{1}{2j}\left[e^{j\theta} - e^{-j\theta}\right]$$

$$\cos\theta = \frac{1}{2}\left[e^{j\theta} + e^{-j\theta}\right]$$

End of Paper